

# Shallow Ocean Bottom BRDF Modeling and Prediction

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## LONG-TERM GOALS

The long-term scientific goal of my research is to better understand the distribution of phytoplankton in the world's oceans through remote sensing their influence on the optical properties of the water. The effect of the bottom reflectance in shallow waters is an obvious extension of this goal, both through its relationship to remote sensing (diffuse reflectance is a remote sensing problem) and through its influence on radiative transfer.

## OBJECTIVES

This is a new project focussed on modeling the spectral bidirectional reflectance distribution function (BRDF) of shallow sea beds. Recent measurements of the BRDF along with concurrent measurements of the sediment properties (composition, grain size, etc.) have prompted us to try to apply the radiative transfer simulation capabilities that we have developed to relate the sediment properties to the BRDF.

For a closely packed assemblage of particles with sizes (equivalent volume spherical diameter) greater than about 100 micrometers, it is known that geometrical optics provides an adequate description of the propagation of light, so ray-tracing techniques can be used to study radiative transfer in such media. However, work on planetary regoliths has suggested that simple solutions of the radiative transfer equation can also be applied to understand the gross features of diffuse reflection from such material. So, can we use classical radiative transfer theory to understand the BRDF, or must we rely solely on ray tracing?

For a number of years, we have been engaged in ONR-sponsored research in radiative transfer in natural water bodies. This research is summarized in *Gordon [2002]*. The goal of our nearly completed project "Inverse Problems in Hydrologic Radiative Transfer" (N000149910007) is to examine the retrieval of the water's inherent optical properties (IOPs), e.g., profiles of spectral absorption  $a$  and backscattering  $b_b$  coefficients from profiles of apparent optical properties (AOPs) — up- and downwelling irradiance  $E_u$  and  $E_d$ , or upwelling radiance  $L_u$  and downwelling irradiance. In addition, earlier work (sponsored by NASA) on inverse methods in atmospheric radiative transfer [*Wang and Gordon, 1993; Gordon and Zhang, 1995; Zhang and Gordon, 1997a, 1997b*] led to methods of retrieving the atmospheric IOPs from transmitted (sky) radiance measured at the Earth surface and reflected radiance measured at the top of the atmosphere. We believe that these inverse techniques, applied to the diffuse reflectance and transmittance of sediment samples, can be used to provide IOPs that, when introduced into the RTE, will reproduce the BRDF.

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Thus, the goals for this project are (1) to be able to explain measured BRDFs using Monte Carlo ray tracing, (2) to develop a means of estimating bottom IOPs (from simple transmittance and reflectance measurements of samples) with which classical radiative transfer methods can be used to predict the BRDF, and (3) to relate the resulting RTE-based IOPs to the physical properties of the particles, e.g., size, packing, etc.

## **APPROACH**

The PI and G.C. Boynton are collaborating with Ken Voss' group that is making measurements of the BRDF and the BTDF (bidirectional transmittance distribution function) of samples of sediment as of various thicknesses. As part of the study, this group is carrying out similar measurements on prepared samples consisting of monodisperse spheres of known refractive index. Gordon and Boynton will begin by carrying out a computational-theoretical study involving only spherical particles; next we will compare our results with the measurements on prepared dense suspensions of spheres; finally, we will make similar comparisons with measurements made on actual benthic zone sediments.

## **WORK COMPLETED**

We have nearly completed development of a ray trace program that utilizes the shape and position of each particle to compute the BRDF and the BTDF for a collection of spheres. This will be used to (1) compare with Voss' experimental measurements on spheres, and (2) to produce synthetic data for the application of inverse methods.

## **RESULTS**

As the initial computer codes are not yet complete, there are no specific results at this time.

## **RELATED PROJECTS**

We are collaborating with Ken Voss on this project. His group is making the experimental measurements.

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## HONORS/AWARDS/PRIZES

NASA Group Achievement Award 2002 to H.R. Gordon as part of the MISR Science Team.

Aqua Outstanding Teamwork Award 2003 (NASA) to H.R. Gordon as part of the MODIS Science Team.